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# Neurosurgical Microvascular Bypass for Stroke

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*A review of the present status of neurosurgical vascular bypass for problems of cerebrovascular occlusive disease is presented. In 70 patients who have undergone operations by one surgical team, the results are most encouraging in cases of transient ischemic attacks with hemodynamic lesions previously considered inoperable or inaccessible in the cerebral vasculature. The morbidity rate is acceptable and the present operative mortality rate is 1.4 percent.*

*Surgeons have made rapid and dramatic advances in the treatment of people with occlusive vascular diseases in the upper chest and neck. Perhaps we could encourage them to think of ways of going inside the head and modifying the circulation there, for at present even those individuals who have occlusive disease in the vertebral canal are not surgically approachable.*

—H. G. WOLFF, MD, *Professor of Neurology, Princeton Conference on Cerebrovascular Disease, 1961*

IN THE PAST several years a number of papers have described the preliminary indications and early results of a neurosurgical microvascular bypass operation designed to increase the collateral blood supply in problems of occlusive cerebrovascular disease.<sup>1-7</sup> This surgical approach was originally developed by Yasargil and Donaghy eight years ago.<sup>8,9</sup> The symptoms in patients who met the criteria for surgical operation were felt to be due to hemodynamic insufficiency rather than

embolic episodes. The surgical technique was described and, although the initial results were promising, a longer follow-up was required to observe the effect of microvascular bypass surgical procedures on the future clinical course of these patients. It also was felt necessary to evaluate (arteriographically, if possible) the patency rates of the surgical bypass postoperatively in a larger series of patients than those previously presented.<sup>10</sup>

This paper describes the results in 70 patients who have undergone a microvascular bypass neurosurgical procedure and who have been followed from 6 to 48 months postoperatively (see Table 1). Most patients in the group reported here were suffering from transient ischemic attacks (TIA) or had suffered a "completed stroke" with pronounced recovery and subsequent mild residual neurological deficit (Table 2). Arteriographic findings are shown in Table 3.

## Stroke as a Clinical Problem

Stroke is the primary neurological health problem occurring in the nation today. Approximately 450,000 new strokes occur per year<sup>11</sup> of which 80 percent are due to cerebral vascular occlusive dis-

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ease.<sup>12</sup> In contrast, only 5 to 10 percent are due to subarachnoid hemorrhage, a major interest in the neurosurgical literature. It is estimated that 2 million people in America are presently disabled and unemployable as a result of stroke. The majority of such persons are under 65 years of age and are in the so-called "preretirement" or productive years.<sup>13</sup>

### Cerebral Vascular Occlusive Disease and Arteriographic Findings

In patients in whom transient ischemic attacks have developed, there is a 13 to 60 percent chance of a completed stroke occurring within four years.<sup>14-17</sup> The outstanding aim of stroke therapy,

therefore, is to prevent such a disaster and, if possible, to improve the quality of life.

A recent analysis of 123 consecutive patients presenting with transient ischemic symptoms at a university vascular clinic showed that 19 percent (N=23) had a completely occluded internal carotid artery as the cause of the hemodynamic cerebrovascular insufficiency. In a short follow-up period three patients of the 23 suffered a completed stroke.<sup>18</sup>

In the National Cooperative Study, arteriographic investigation showed that 6 percent of the patients studied had purely inaccessible lesions in the cerebral vasculature.<sup>19</sup> An additional 16 percent of patients studied for cerebrovascular symptoms were shown to have old completed internal carotid occlusions, which, at present, are considered inoperable because of the low success rate of reopening the vessel.<sup>20,21</sup> Therefore, in 22 percent of patients studied by arteriography, "inoperable or inaccessible lesions" with present conventional surgical techniques may be present. This potentially amounts to approximately 15,000 persons per year presenting with transient ischemic attacks without permanent neurological deficit.

TABLE 1.—Analysis of Bypass Status, January 1975

Number of cases	70
Men	85%
Women	15%
Over 65, retirement years	25%
Under 65, working years	75%
Average age preretirement, most patients in late 50's	62 yrs
Minimum follow-up	6 mos
Average follow-up	16 mos

TABLE 2.—Types of Clinical Presentation

	Number	Percent
TIA or RIND	41	58
"Completed stroke"		
Mild	18	25
Moderate	3	5
Severe	5	7
Progressive stroke	3	5
TOTAL	70	

TIA=transient ischemic attack, neurological dysfunction under 24 hours with complete recovery

RIND=reversible ischemic neurological deficit, neurological dysfunction over 24 hours with complete recovery

Mild=clumsiness of hand or leg, fluctuating at times, fluctuating dysphasia

Moderate=hemiparesis or monoparesis, dysphasia nonfluctuating

Severe=hemiplegia, monoplegia, aphasia

Progressive=progressive loss of neurological function

TABLE 3.—Arteriographic Findings

	Number	Percent
BICO	11	16
ICO	25	35
SS	13	19
MOS	9	13
MCS	6	8
MCO	6	8
TOTAL	70	

BICO=bilateral internal carotid occlusion

ICO=internal carotid occlusion

SS=siphon stenosis (cavernous portion of carotid artery)

MOS=middle cerebral occlusion and stenosis (intra- or extra-cranial)

MCO=middle cerebral occlusion

MCS=middle cerebral stenosis

### Theoretical Basis of the Surgical Procedure

Based on Baker's extensive research on cerebral vascular occlusive lesions (amount of atherosclerosis deposited equals blood pressure times radius of vessel), this surgical approach may bypass the major obstructive pathology (Premise No. 1)<sup>22,23</sup> and surgically supply an additional collateral blood supply to ischemic areas. Since "hemodynamic" cerebrovascular insufficiency symptoms are the result of insufficient collateral supply rather than the block itself (Premise No. 2)<sup>24-27</sup> such a surgical procedure may alleviate the symptoms and signs of cerebral ischemia. Whether such a surgical operation can partially or completely improve mild cerebrovascular neurological defects is still open to debate (Premise No. 3). Some pathological studies have suggested that minor neurological deficits could be improved at least theoretically with the restoration of normal perfusion pressures to the areas of marginal flow.<sup>28,29</sup> At present, however, there is no reliable clinical method of determining in advance which neurons are poorly functioning because of partial anoxia or which neurons are, in fact, dead.

### Present Indications for Surgical Operation

Indications for the microvascular bypass procedure fall into two categories: lateralized low perfusion syndromes and generalized low perfusion syndromes.

#### *Lateralized Low Perfusion Syndromes*

The symptoms in this category depend on the vessel involved (usually middle cerebral artery) and the functional collateral supply available; may be transient, progressive or fluctuating.

The types of causes are several:

- Old internal carotid occlusions with poor collaterals.
- Carotid (inaccessible) stenosis with poor collaterals.
- Middle cerebral stenosis with poor collaterals (atherosclerotic or vasculitis).
- Middle cerebral occlusions with mild or moderate deficit and absent recanalization and poor collaterals.
- Vertebral basilar lesions with poor collaterals.<sup>30</sup>
- Inoperable giant intracranial aneurysms due to poor collaterals.<sup>31</sup>

#### *Generalized Low Perfusion Syndromes*

There is a smaller group of patients who suffer from a generalized ischemic cerebrovascular syndrome due to multiple large vessel occlusive disease. In these persons, symptoms such as dizziness; incoordination; blurred vision; syncope; dementia, and transient motor, speech or sensory deficits may be noted.

Two causes may be given in this category: multiple vessel occlusions and multiple vessel inaccessible stenoses.

### Surgical Technique

On the basis of hemodynamic principles and the determination of the most suitable cortical artery, Yasargil's initial operative approach was modified. First, a wide-based "U" shaped temporal or occipital flap incorporating the donor vessels and overlying the angular gyrus is reflected. A 4 cm craniectomy is fashioned at a point 6 cm above the external auditory meatus. This operative technique consistently exposes the vessels around the angular gyrus. With the use of an operating microscope, bipolar coagulation and

microsurgical techniques, the superficial temporal artery or occipital artery is dissected free from its subcutaneous bed. The arachnoid is then carefully opened around the cortical vessel of appropriate size. A 5 mm segment of this cortical artery is isolated between two small atraumatic clamps. The tip of the superficial temporal artery is freed of its adventitia and an end-to-side anastomosis is then carried out with 10-0 interrupted nylon sutures. The craniectomy opening is covered with a 4 cm plastic disc which has a slit opening for passage of the superficial temporal artery. When the scalp is finally replaced, care is taken not to compress the superficial temporal artery.

The primary morbidity risk stems from the technical requirement to clamp a portion of the recipient cortical artery for approximately 20 minutes in order to carry out a satisfactory anastomosis in a bloodless field. When minor neurological deficits do occur postoperatively, the vast majority tend to clear spontaneously, if the cortical branch occlusion time is 30 minutes or less. An experienced surgical team is therefore a necessity.

The temporal lobe tip vessels as recipient candidates for the bypass have been abandoned because of two failures in patency attributed to technical problems due to the minute size (less than 1 mm) of the available cortical artery in this location. The post-temporal-angular cortical artery complex above the ear has been used exclusively and in the past 90 cases (September 1975) no major difficulties have been encountered in finding a suitable recipient vessel of sufficient size even though a small, well-localized craniectomy was utilized.

### Analysis of Results

In a significant percentage of patients suffering from transient ischemic attacks, there is symptomatic relief following the surgical bypass. Therefore the quality of their lives is improved (see Table 4).

At the Mayo Clinic, investigators have extensively followed a series of 200 patients suffering from definite transient ischemic attacks clinically. In the Mayo group the stroke occurrence rate after 16 months was 22 percent.<sup>16</sup> In our series to date (with a similar follow-up period) the stroke occurrence incidence is 7 percent including those patients who suffered a stroke in the distribution of a vessel not supplied by the bypass. The inci-

dence of stroke in the hemisphere supplied by the bypass is 3 percent at present. It may be that in the future bilateral "surgical arterial bypasses" should be pursued more aggressively in patients with multiple vessel disease. The improvement rate in progressive and mild completed strokes was 62 percent (see Table 4). This statistic, of course, must be viewed cautiously as the natural history of spontaneous improvement in completed strokes is quite variable.

TABLE 4.—Results of Clinical Therapy to Date

	Number	Asymptomatic or Improved Percent
TIA or RIND .....	41	83*
Progressive .....	3	100
"Completed stroke"		
Mild .....	18	55†
Moderate .....	3	33
Severe .....	5	0
TOTAL .....	70	

Average follow-up 16 months.

See Table 2 for definitions of other terms used.

\*One transient ischemic attack or less postoperatively.

†Objective evidence of postoperative improvement in speech, writing and daily tasks.

TABLE 5.—Complications

	Number	Percent
<b>Morbidity</b>		
Transient speech difficulty all cleared (dysphasia) .....	5	7.0
Transient weakness all cleared .....	2	3.0
Permanent increase in deficit, moderate parietal lobe dysfunction .....	1	1.4
Wound infection superficial, no surgical operation required .....	1	1.4
Marginal scalp ischemia, no surgical operation required .....	5	7.0
Subdural hygroma, all evacuated uneventfully .....	3	4.0
<b>Mortality*</b>		
<b>Operative</b>		
Under 7 days, stroke opposite side ..	1	1.4
Under 30 days, GI hemorrhage—acute bleeding from chronic duodenal ulcer with intestinal perforation; 23 days postoperatively .....	1	1.4

\*As of November 1975, operations have been carried out in 102 patients with no further mortality.

TABLE 6.—Patency Rates of Bypass Postoperatively

	Percent
Doppler ultrasound auscultation	
over bypass .....	70/70 100
Apparently open .....	65/70 93
Postoperative arteriograms, total cases ..	50/70 70
Patent on arteriograms .....	47/50 94

## Discussion

The only death occurring within the first week after surgical operation was a stroke involving the opposite hemisphere from an embolic clot to the opposite intracranial carotid artery. The other death, occurring within the first month of operation, from gastrointestinal hemorrhage, could probably be avoided now by vigorous antacid regimes in all patients since they are usually placed on aspirin for one month postoperatively to aid in avoiding platelet clumping at the fresh bypass anastomotic sites (see Table 5). Patency rates of bypass postoperatively are shown in Table 6.

Objective evaluation of the effects of any new operation may be difficult to obtain. The ultimate test of whether this particular operative approach is useful clinically will be a comparison between similar groups of patients (operated versus non-operated) suffering from angiographically-shown inaccessible or inoperable cerebrovascular stenotic or occlusive lesions. In this age of "consumerism" and the patient's "bill of rights" there is some doubt that a reliable double blind randomized study can be implemented in this country. This is particularly true in states (such as California) where the emphasis on informed consent including discussion of the "alternatives of treatment" have such widespread implications in malpractice litigation.<sup>32</sup>

Several investigators have reported significant improvement in regional cerebral blood flow following such a bypass (allowing for the intrinsic errors implicit in the methods employed).<sup>6,33,34</sup> Other workers have documented a significant increase in retinal artery perfusion pressures following bypass for symptomatic internal carotid occlusions.<sup>35</sup>

These results, therefore, must continue to be considered preliminary in nature but in comparison to the available statistics on the natural history of cerebral vascular occlusive disease, surgeons involved in this aspect of neurosurgical therapy remain encouraged.

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